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PREPARATION AND APPLICATION OF DIFFERENT CARBON BASED THIN FILMS

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ABSTRACT

Due to its possibility to form different structures, carbon based thin films can cover an extreme wide field of properties. Additionally the possibility to prepare nanostructured carbon based coatings further enhances this spectrum.

In the following some examples showing the versatility for different fields of applications are given.

Index Terms – Thin films, carbon, diamond, UNCD, DLC, mechanical stress, field emission

1. INTRODUCTION

Carbon based thin films appear in a very wide variety of structures – from single crystalline diamond over micro- and (ultra)nanocrystalline diamond to amorphous diamond like carbon (DLC) and graphite; furthermore by addition of / doping with other elements (e.g. H, N, Si,...) the bandwidth of structures can be furthermore significantly enhanced. An additional degree of freedom comes up with nanostructuring of these materials – that can be performed either on morphology or on structural / chemical composition -, leading to properties that are not available else and may lead to superior performance or new technical applications.

2. RESULTS

2.1. Ultrananocrystalline Diamond Films

Ultrananocrystalline Diamond films (UNCD) have been deposited by microwave plasma CVD. It is shown that the properties of this nanostructured material has to be regarded as consisting of an amorphous matrix with embedded diamond crystals having some nanometers diameter; by aimed design of the amorphous matrix the properties can be tailored [1], especially the mechanical stress can be adjusted even to zero [2], Fig. 1, and the coefficient of thermal expansion (CTE) can be adopted to that of silicon [3]. This is of interest for several applications like MEMS or SAW-filters.

Additionally it is shown that the deposition process can be controlled by Optical Emission Spectroscopy (OES) of the plasma [4].

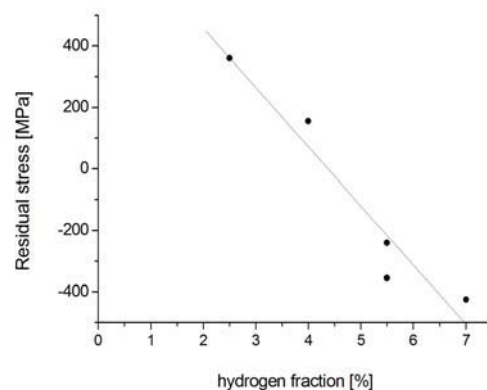


Figure 1: Mechanical stress as a function of H_2 admixture

Furthermore it is shown that the mechanical stress can be determined with spatial resolution and on “3D”-samples by deconvolution of the Raman-spectra from the transpolyacetylene-peak, Fig. 2:

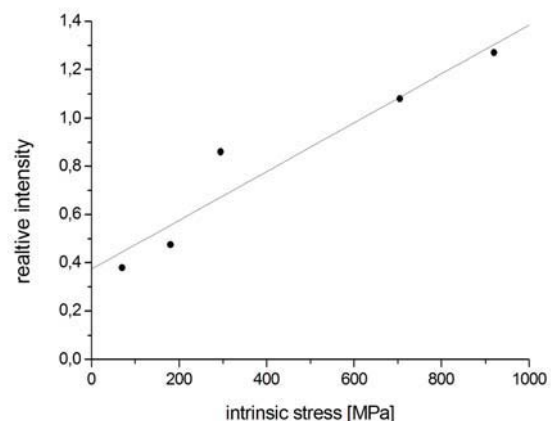


Figure 2: Raman-intensity of the 1480 cm^{-1} peak (normalized by G-peak intensity) as a function of mechanical stress

2.2 Al-doped nanostructured C-films

Al-doped nanostructured graphitic films have been deposited by RF-ICP plasma CVD from metalorganic precursors. These films can show platelet-like tips perpendicular to the substrate surface, Fig. 3, leading to field enhancements (of electrical fields).

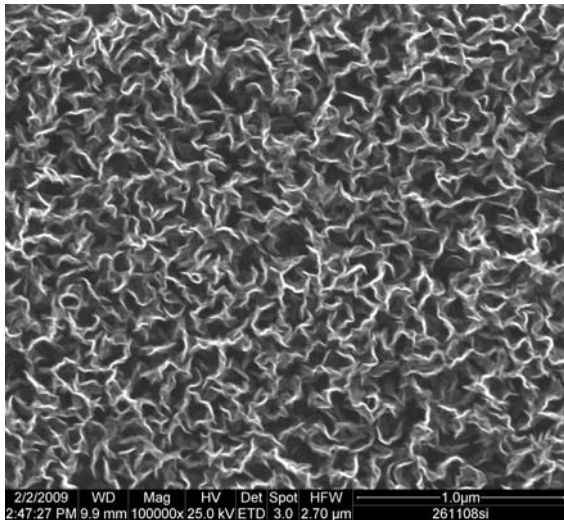


Figure 3: SEM-picture

By optimizing this effect, electron field emission could be observed down to fields of 3 Volts/micrometer, Fig. 4:

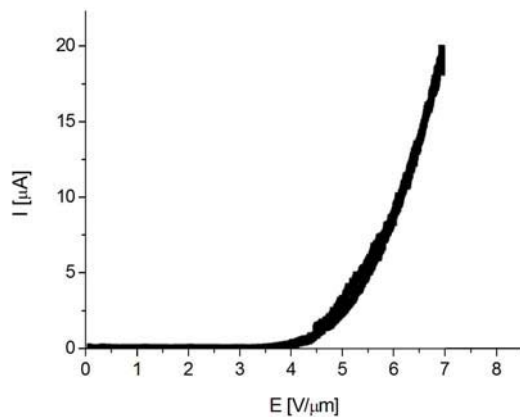


Figure 4: Field emission current as a function of applied field

Thus this material may be promising for field emission devices.

2.3 a-C:H / a-SiC multilayers

Barrier coatings have widespread technical applications from food packaging to biomedical implants or OLEDs. The problem solved here was the protection of NdFeB-magnets from hydrogen in UHV (where usually the only residual gas component is hydrogen). It is well known that NdFeB-magnets are destroyed by transcrystalline H_2 corrosion [5] after some minutes at 100 mbar ... 300 mbar.

Usually the transport of substances through solids is dominated by migration through grain boundaries, thus amorphous materials which are free from grain boundaries are preferred. Furthermore multilayers give a further degree of freedom to tailor additionally mechanical stresses and adhesion of the coating. Thus a multilayer system consisting of a-C:H / a-Si_xC_y layers has been developed. It is deposited using CCP-RF-plasma CVD by modulation of the precursor gas flow (CH_4+H_2 and $Si(CH_3)_4$). The optimized system did not fail in 182 h at 700 mbar H_2 – this criterion was predefined as benchmark for this application, Fig.5:

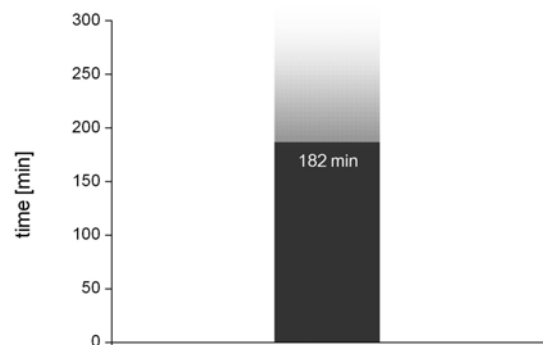


Figure 5: Lifetime of coated magnets

2.4 Vacuum arc deposited a-C films

Vacuum arc plasma sources are a promising tool for high rate, large area deposition because at high power levels the plasma likes to contract into an arc discharge, Fig. 6:

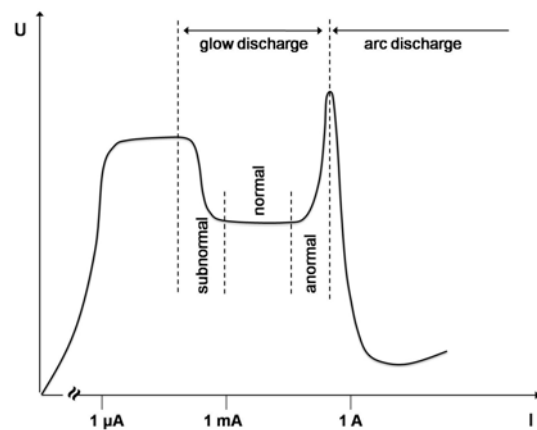


Figure. 6: Voltage / current characteristics of DC-discharges

The drawbacks of cathodic arc sources – the emission of macroparticles – can be overcome by using anodic arc techniques or thermionic vacuum arcs (TVA).

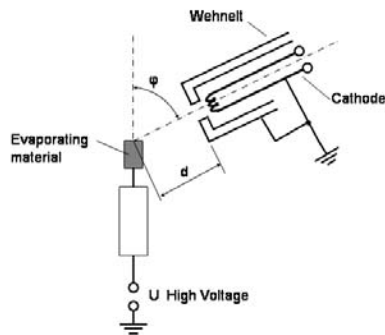


Figure 7 Principle of TVA

Hard carbon thin films produced by these plasma sources are of interest e.g. for solar cell applications as protective AR layers.

Amorphous carbon films could be deposited by these techniques in a very broad range, Fig. 8:

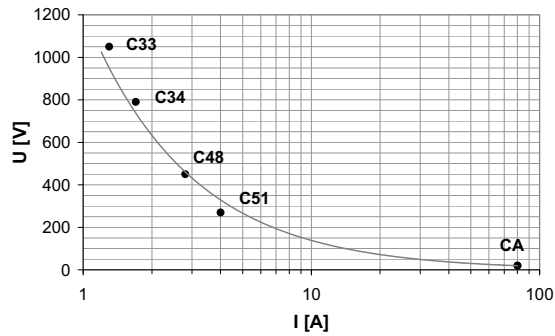


Figure. 8: Working points of deposited films (C33 – C51: TVA, CA: anodic arc)

The sp^3 -content of these films was determined from the XAES spectra using the so called D-value [5] that was calibrated with pure diamond and HOPG, Fig. 9:

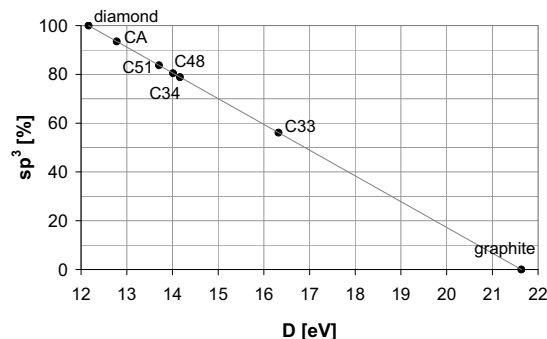


Figure 9: Calibration curve of D-value

It is shown that the sp^3 -content depends on the working point of the discharge and can be adjusted between ca. 50 % and ca. 90 %, without any additional substrate bias, Fig. 10:

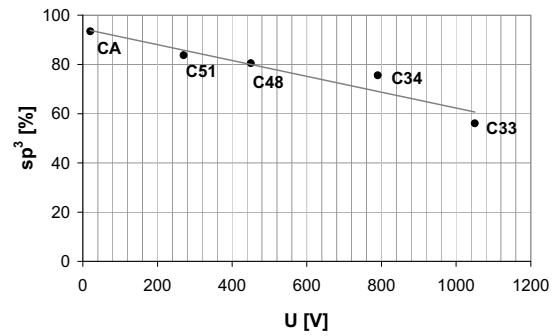


Figure 10: sp^3 -content of deposited films

Thus by modulation of the voltage (or current) applied nanostructured sandwiches can be obtained. It is expected that by this technique films with superior mechanical properties can be obtained via the “supermodulus effect” [6]. One application could be tailoring of the wear particle size distribution that seems to be a key to improve the lifetime of artificial hip joints [7] – up to now it could be shown that the size distribution can be significantly influenced even if the final goal – all particles at ca. 1 μm – has not yet been reached, Fig. 11:

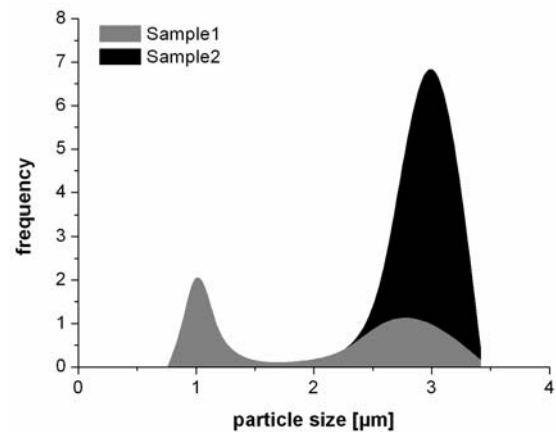


Figure 11: Size distribution of wear particles

2.4 Electrodeposited carbon films

Last but not least we started to produce diamond like carbon films by liquid-electrodeposition to avoid expensive vacuum equipment usually needed.

The films are deposited on silicon substrates from a liquid consisting of methanol, water and glycerol using pulsed DC-discharge (1kV, 4.2 kHz and 50% duty cycle) and are characterized e.g. by Raman spectroscopy, Fig. 12:

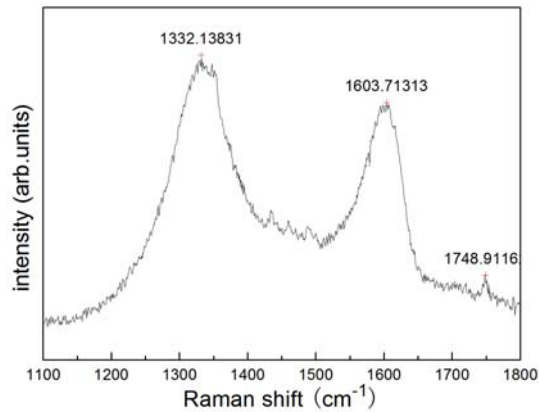


Figure 12: Raman spectra of deposited films

One finds the D- and G- band typical for DLC [8].

3. CONCLUSIONS

Carbon based thin films with different structures have been deposited using PVD- and CVD plasma sources operated from DC-arcs to microwave-plasmas and optimized for several challenging applications.

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5. ACKNOWLEDGEMENTS

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